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TODAY'S PROBLEMS TOMORROW'S CRISES

A Report of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology

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About the National Science Board Commission on Precollege Education in Mathematics, Science and Technology

In response to the current decline in the quality and quantity of precollege mathematics and science education in the United States, the National Science Board (NSB) established the Commission on Precollege Education in Mathematics, Science and Technology. The NSB Commission is composed of 20 persons from a wide variety of fields and is co-chaired by William T. Coleman, Jr. and Cecily Cannan Selby.

The purpose of the NSB Commission is to define a national agenda for improving mathematics and science education in this country. It will develop an action plan that will include a definition of the appropriate roles and responsibilities of federal, state, and local governments, professional and scientific societies, and the private sector in addressing this problem of national dimension.

The Commission will be active over a period of 18 months and will issue interim reports on its findings. The Commission is charged to:

- Examine the existing evidence on the quality of precollege (all classes, K-12) education in mathematics and science;
- Identify where current practices and policies fail to ensure the entry, selection, education and utilization of the full range of potential talent in science, mathematics and engineering;
- Identify and analyze existing mathematics and science programs, teaching materials and teaching techniques whose success may justify imitation or adaptation;
- Develop an understanding of the roles that all systems—government and private organizations, professional groups and individuals—can play in improving mathematics and science education;
- Establish a set of principles, options and strategies which can be used to improve the quality of secondary school science and mathematics education.

About the National Science Foundation

The National Science Foundation (NSF) was established on May 10, 1950, as an independent agency of the Executive Branch of the Federal Government. Public Law 507 of the 81st Congress states that the "Foundation shall consist of a National Science Board (NSB) and a Director." The NSF Act assigns policy-making functions to the National Science Board and the administration of the Foundation to the Director. The policies of the Board on the support of science, development of scientific manpower and improvement of science education are generally implemented through the various programs of the Foundation.

NATIONAL SCIENCE BOARD
NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

NSB COMMISSION ON PRECOLLEGE
EDUCATION IN MATHEMATICS,
SCIENCE AND TECHNOLOGY

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October 18, 1982

Dr. Lewis M. Branscomb
Chairman
National Science Board
National Science Foundation
Washington, D.C. 20550

Dear Dr. Branscomb:

We are most pleased to transmit to you the first formal report of our Commission, "Today's Problems, Tomorrow's Crises." This report represents the Commission's assessment of the condition of precollege education in mathematics, science and technology in this country.

The problems summarized in our report--if left unresolved--will escalate in the years ahead. Thus, all Americans need to recognize the broad importance of mathematics, science and technology in the education of our youth. We hope, accordingly, that our report will receive wide dissemination.

The seriousness of the current situation underscores the Commission's resolve to develop, during the remainder of its life, an agenda for action for all sectors of society.

Sincerely,

William T. Coleman, Jr.

Cecily Cannan Selby

Today's Problems, Tomorrow's Crises

Introduction

Across the United States, there is escalating awareness that our educational systems are facing inordinate difficulties in trying to meet the needs of the Nation in our changing and increasingly technological society. We appear to be raising a generation of Americans, many of whom lack the understanding and the skills necessary to participate fully in the technological world in which they live and work. Improved preparation of all citizens in the fields of mathematics, science, and technology is essential to the development and maintenance of our Nation's economic strength, military security, commitment to the democratic ideal of an informed and participating citizenry, and leadership in mathematics, science and technology.

To meet these ends, our formal and informal education systems must have the commitment and the capacity to achieve three equally important goals:

- to continue to develop and to broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science and engineering;
- to widen the range of high-quality educational offerings in mathematics, science and technology at all grade levels, so that more students would be prepared for and thus have greater options to choose among technically oriented careers and professions; and
- to increase the general mathematics, science and technology literacy of all citizens for life, work and full participation in the society of the future.

The first goal needs little explanation, since maintenance of U.S. scientific and technological capacity requires superbly educated mathematicians, scientists, and engineers. As the total number of 18-year-olds in the population continues to decrease into the 1990's, the percentage of high school graduates entering preprofessional, college-level courses in science and engineering must increase to meet future manpower needs. In addition, to meet the country's needs for excellence, creativity, and innovation in its scientific work, we must develop and utilize the talents of all Americans, including women and minorities (now currently underrepresented in the science and engineering professions).

The critical value of the second goal has become widely recognized during the past few years. The current gap between opportunities for those with and without credentials in mathematics, science and technology will increase dramatically as the technological complexity of U.S. society increases. Industrial leaders have identified the current shortage of trained technicians as a serious barrier to increased productivity. Military commanders echo this concern about their manpower requirements for meeting national security needs. In such professions as law, journalism, and business management, there is also a growing demand for men and women with backgrounds in mathematics, science, and technology. The current and increasing shortage of citizens adequately prepared by their education to take on the tasks needed for the development of our economy, our culture, and our security is rightly called a crisis by leaders in academe, business, and government.

The third goal is rooted in Thomas Jefferson's familiar dictum that an educated citizenry is the only safe repository of democratic values. The life and work of Jefferson and others make clear that a broad understanding of the relationships between science and society was considered by early Americans as integral to the ideal of the Republic. To lead full lives and to participate with confidence in contemporary American society, citizens need an understanding and appreciation of mathematics, science and technology.

This report reviews the status of math, science and technology instruction in our educational systems and explores some of the key problems and challenges facing those systems. The central conclusion to be drawn is that, in the aggregate, the U.S. educational systems currently are not satisfactorily achieving the second and third goals, and they will need assistance, although perhaps to a somewhat lesser extent, to meet the first.

The Principal Concern: Declining Achievement and Participation at a Time of Increasing National Needs

Data from a number of sources have documented declining student achievement in mathematics and science, as indicated by declines in:

- science achievement scores of U.S. 17-year-olds as measured in three national assessments of science (1969, 1973, and 1977);
- mathematics scores of 17-year-olds as measured in two national assessments of mathematics (1973, 1978); the decline was especially severe in the areas of problem-solving and applications of mathematics;
- mathematical and verbal Scholastic Aptitude Test (SAT) scores of students over an 18-year period through 1980; and
- students prepared for post-secondary study. Remedial mathematics enrollments at four-year institutions of higher education increased 72 percent between 1975 and 1980, while total student enrollments increased by only seven percent. At public

four-year colleges, 25 percent of the mathematics courses are remedial; and at community colleges, 42 percent are.

The proportion and qualifications of high school seniors who will major in mathematics, science, and engineering have remained roughly constant over the past 15 years, although college engineering enrollments have increased steadily since the mid-1970's. Some students are also receiving more advanced experiences in secondary school science and mathematics as indicated by performance on advanced placement tests.

Nonetheless, adequate mathematics and science course opportunities are not available for *all* talented and motivated students. As many as one-third of U.S. secondary schools do not offer sufficient mathematics to qualify their graduates for admission to accredited engineering schools. Only one-third of the 21,000 U.S. high schools teach calculus, and fewer than one-third offer physics courses taught by qualified physics teachers.

The evidence on student participation and achievement indicates a wide and increasing divergence in the amount and quality of the mathematics, science and technology education acquired by those who plan to go on to college and study in those areas and by those who do not. Students in the latter category generally stop their study of mathematics and science at a relatively early age, perform considerably less well on achievement measures than the career-bound, and do not have opportunities to pursue appropriate courses in contemporary technology. Only nine percent of the students graduating from vocationally oriented secondary school programs in 1980 took three years of science, and only 18 percent took three or more years of mathematics. Hence, it is clear that while the first goal stated in the introduction presently is being fulfilled reasonably well, the second and third goals are not. In fact, the educational system may actually have carried out these latter goals better 20 years ago: the proportion of public high school students (grades 9 to 12) enrolled in science courses has declined since that time. Thus, the principal concern with student participation and achievement is with those who do not plan careers in mathematics, science, or engineering.

In addition, wide differences persist in achievement and participation levels among students from different social groups. Women have traditionally participated less than men in science, and members of various minority groups (specifically, if not exclusively, American Indians, Black Americans, Mexican Americans and Puerto Ricans) have participated less and performed less well on standard science and mathematics achievement tests than their white counterparts. Approximately 20 percentage points separated the mathematics achievement scores of 17-year-old black and white students on national assessment tests in both 1973 and 1978. Ap-

proximately 15 percentage points separated 17-year-old Hispanics and whites in both years. Between 1973 and 1978, nine-year-old black students showed a definite improvement in performance on mathematics achievement tests, while the average performance of nine-year-old white students declined and that of Hispanics remained constant.

Specific Contributory Problems

Studies and analyses of conditions in the U.S. educational system—including both its formal and its informal components—point to four problems that contribute to declining student participation and achievement levels.

Teachers

Individual teachers have considerable discretion in the selection of course content and instructional approaches and, therefore, play a pivotal role in the education of students. Superior teachers of mathematics, science and technology can motivate students to do well in their courses and can stimulate students to take more advanced courses and consider technically or scientifically oriented careers. Mediocre and poor teachers may dampen the enthusiam of good students and fail to recognize and stimulate the development of potential talents in others. Therefore, the documented shortage of superior teachers must be considered a prime contributing cause of decreasing student participation and achievement in mathematics, science and technology.

There is also a growing shortage of qualified secondary school mathematics and physical science teachers. In 1981, 43 states (of 45 responding) reported a shortage of mathematics teachers. For physics teachers, 42 states reported such shortages. In the same year, 50 percent of the teachers newly employed nationwide to teach secondary science and mathematics were actually uncertified to teach those subjects. From 1971 to 1980, student teachers in science and mathematics decresed in number—threefold in science and fourfold in mathematics—and only half of them have actually entered the teaching profession. In addition, 25 percent of those currently teaching have stated that they expect to leave the profession in the near future.

Some of the problems that affect the participation and achievement of students at all grade levels are:

- Among certified teachers of high school mathematics and science, very few have had the formal educational preparation required to provide students with an understanding of modern technology.
- There are few available opportunities for certified mathematics and science teachers to update or broaden their skills and backgrounds. Such training opportunities are essential due to the rapid advances taking place in mathematics, science and

technology and the need to introduce new types of upper level courses for nonspecialists.

- There are few inservice programs to certify teachers who are presently not qualified to teach mathematics and science.
- Most teachers in the primary and middle school grades have not had training in science and mathematics or courses in methods to teach these subjects.
- District-level supervision has been reduced as a result of financial retrenchment or has been shifted from instructional to administrative support. As a result, relatively few people are available outside the classroom to provide quality control or to assist teachers with pedagogical problems.

Classrooms

Deficiencies in the numbers and qualifications of mathematics and science teachers are exacerbated by classroom conditions, including inadequate instructional time, equipment, and facilities.

The time available for adequate instruction in U.S. schools is far more limited than in other advanced countries. In the United States, the typical school year consists of 180 days, as contrasted with 240 days in Japan. This is further reduced by absenteeism, which amounts to an average of 20 days per school year. The typical school day is five hours long, compared with six- or eight-hour days in other countries. In addition, many periods of varying length throughout school days and weeks are devoted to non-academic pursuits, both reducing the hours available for instruction and diverting the time and energy of teachers to noninstructional duties. Problems associated with student discipline and motivation, which are severe in some schools and affect the general learning environment, have been well publicized.

Many science courses in schools throughout the country are being taught without an adequate laboratory component or with no laboratory at all. In some cases, laboratory apparatus is obsolete, badly in need of maintenance, or nonexistent. In other cases, such apparatus is not used because of a lack of paraprofessionals or aids to set up and maintain equipment, a condition that has become increasingly important due to the greater concern for safety in the schools.

Curricula

Curricula in mathematics and in several scientific disciplines were developed with federal support two or more decades ago to provide rigorous, modern course work for high school students interested in careers in mathematics, science and engineering. These curricula, and several generations of privately-developed successors, continue to serve their purpose, though many need to be revised.

Mechanisms must be developed to incorporate effectively into the curricula changes associated with advances in the disciplines and evolving contemporary technologies.

Another curricular concern is that upper level high school courses based on these curricula are too abstract and theoretical for most students. In fact, serious doubts exist about whether many of the commonly offered mathematics, science and technology courses in the secondary schools are, in their present form, of much value to students planning careers outside of mathematics, science or engineering. Few courses or widely accepted curricula are available with the explicit aim of providing such students with adequate preparation in mathematics and science. In addition, courses associated with modern technology are not available; most courses, in fact, make little reference to technology at all.

In the lower grades, mathematics courses emphasize basic computational skills rather than interpretation and application. Science courses at those levels often are empty of content and, generally, do not build upon the work of previous grades.

Appropriate courses in modern technology are not available. Few systematic attempts are made to integrate learning in mathematics, science and technology. As a result, little coherent preparation is offered for the disciplinary courses (usually earth science and biology) encountered for the first time in the ninth and tenth grades. This condition is particularly unfortunate, because a wealth of information supports the conclusion that students who dislike mathematics and science courses in the early grades, or who receive inadequate instruction in those grades, are unlikely to participate effectively in upper level courses.

Instructional Approaches

In general, precollege mathematics, science and technology instruction has yet to take advantage of the advances in technology and behavioral science of the past 20 years. For example, computers provide an immense opportunity to develop curricula and instructional approaches that might motivate larger numbers of students and increase the flexibility of the programs available to them. Computers and other modern technologies are available in many U.S. schools, and imaginative uses are made of these instructional aids in individual classrooms. However, computer software is generally inadequate, and the full potential of these technologies for instruction has received little attention.

Considerable progress also is being made in research in math and science education. The cognitive sciences are providing a wealth of informatin on the way people learn. For example, knowledge is now available about the relative degree of abstraction that students of a particular age can be expected to grasp. However, such information has yet to be systematically applied either in the

development of mathematics, science, and technology curricula, or in the training of teachers of these subjects.

Finally, there is evidence that many students who have an interest in mathematics, science, and technology are not being reached through instructional approaches currently used in the classroom. Whereas many students do not like school science—and form this opinion by the end of third grade—many do like the science and technology that they see on television. They also like what they encounter at science and technology museums, planetariums, nature centers, and national parks. Many of these institutions facilitate science and technology education with their own after-school, weekend, and vacation classes. In addition, many school classes make field trips to such institutions. Because these programs are apparently more appealing than school science offerings, the innovative instructional approaches used in them should be examined and, where possible, applied to the classroom setting.

Public Perceptions and Priorities

Largely, public schools reflect, rather than determine, public perceptions and priorities. The condition of mathematics, science and technology education reveals an apparent misperception by the public that adequate course work need only be provided to students preparing for college-level study in these fields and that these courses are unnecessary for other students. This is consistent with the broader perception that excellence in science and technology is vitally important to the Nation but that it can and should be left to the experts. Thus, its pursuit has little to do with the day-to-day concerns of most people—except when major news events such as a nuclear reactor accident or a space shuttle launch intrude. This misperception about the mathematics, science and technology training needed by students in our schools is tragic for our society as a whole.

Yet, a reasonable fraction of the adult public is interested in science and technology. This is evident from the recent popularity of science magazines for nonspecialists, quality television and radio programs (particularly in the public media), and science and technology museums. Although a large fraction of the public enjoys science and technology, it appears that many consider school mathematics, science, and technology as isolated from the real world and not essential for most students.

That misperception is part of a public view that the aims, substance, and quality of public education do not reflect the considerable economic, social, and cultural changes that have occurred in this country since the late 1960's. Today, an increasing percentage of the work force is concerned with the retrieval, processing, and transmission of information. Yet, public school mathematics and science courses are, at best, only peripherally concerned and preparing students to work and live in a society that concentrates on such tasks.

Apparently, no consensus has been reached that the future prosperity and international position of the United States depend critically upon broader public attainment in mathematics, science, and technology. In addition, there is no consensus that high quality mathematics, science, and technology education is a matter of national concern, transcending state and local interests and responsibility. Mathematics and science requirements both for high school graduation and for college entry have generally declined over the past 15 years. Although there are some encouraging signs that this trend is reversing, only about one-third of the Nation's 16,000 school districts require more than one year of high school mathematics and one year of science for graduation.

National Science Board Commission

The absence of a national consensus on the importance of mathematics, science, and technology education for all citizens may be the central cause of the critical problem facing our educational systems. A broad national effort is essential. The National Science Board Commission on Precollege Education in Mathematics, Science and Technology has been established to address this condition. The Commission will define, over the next year, a national agenda that should provide an action plan for all sectors of society to use in the achievement of the three important educational goals outlined in the introduction to this report.

Sources

The data appearing in this report have been drawn from the sources that follow. Specific citations and additional references may be obtained on request from the office of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology.

1. National Science Foundation and Department of Education. *Science and Engineering Education for the 1980's and Beyond.* Washington, D.C.: U.S. Government Printing Office, October 1980, primarily Chapter V.
2. National Science Foundation. *Science and Engineering Education: Data and Information 1982. A Report to the National Science Board Commission on Precollege Education in Mathematics, Science and Technology* (NSF 82-30).
3. Papers presented at the National Academy of Sciences' Convocation on Precollege Education in Mathematics and Science, particularly Paul DeHart Hurd, "State of Precollege Education in Mathematics and Science," (May 12-13, 1982).

Members of the Commission

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